Asian Jr. of Microbiol. Biotech. Env. Sc. Vol. 19, No. (4) : 2017 : 779-785

Publications ISSN-0972-3005

STATISTICAL EVALUATION OF BAEDISIFU MINERALIZATION-RELATED STREAM SEDIMENT MAMBERAMO RAYA REGENCY, PAPUA PROVINCE INDONESIA

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(Received 22 February, 2017; accepted 5 April, 2017)

Key words : Baedisifu, Gauttier, Stream sediment, *Proximity matrix*

Abstract–This study aimed to distinguish the mineralization characteristics between igneous and sedimentary rocks in the area, by applying stream sediment method and correlating statistical characteristics of the elements contained. Suplhides metal mineralization which represents by Cu is characterized by closed-relationships with Pb and Zn. The presence of those elements is typical for porphyry copper gold deposits. Based on proximity matrix and dendogram cluster membership, there are six groups of mineralization: (1) Au, W, Bi, Mo (2) As, Sn, Mo, Pb (3) Cu, Pb, Mo, Au (4) Pb, Ag (5) Mo, Au, Sn (6) Ag, Sn. There is a specific feature in these groups, where As, Mo, and Pb are clustered, and in other cluster Cu and Zn. This feature suggesting a mineralization process that produced metal associations of Au-Cu-Mo, Cu-Pb-Zn in a porphyry copper system. Proximity matrix test was also performed on sampels AD/RC-02, AD/ RF-04, AD/RC-05, which resulted an indication that chip samples taken from our cropt and floats (metamorphosed altered andesite-diorite boulders) taken form stream sediment, has a relationship in mineralization process, despite the different kind of the rocks.

INTRODUCTION

The study area is included in the Central and Northern Range of Papua Island. Lithology of the northern range is composed by sedimentary rocks of North Irian Basin (McAdoo and Haebig, 1999) or Mamberamo Basin (Baldwin, 2012), that distributed from the highlands to low relief topography, and at the southern part, metamorphic rocks exposed in highlands topography, in relatively east-west trend. Sedimentary rocks of Unk Formation, Mamberamo Formation, and Makats Formation arrange the Northern Irian Basin. The metamorphic rocks are the members of Baedisifu metamorphic belt which distributed relatively consistent to, and contact with ultramafik rocks of the cycloops ophiolite. In the area of the metamorphic rocks, diorite-diabase intrusions are locally exposed following the regional structure patterns (Dow and Sukamto, 1984) (Figure 1). Waschmuth and Kunst (1986) reported that the diorite intruded the metamorphic and sedimentary units, where the outcrops occurred as a structural contacts which distributed locally.

A thick sediments covers outcrops of sandstone, siltstone and conglomerate along the Baedisifu River. Some characteristic physical features were recognized on the sedimentary rocks which were considered as indications of mineralization zones, such as changing of colors to dark grey and reddish grey, and the occurrences of irregular quartz veins, pyrite, oxidation zones, silicifications and sulphides.

During the field works, stream sediment sampling program was not easy to perform due to some obstacle factors, such as natural conditions of the Papua tropical forest, steep topography, uncertainity of the weather, difficulties to find transportation tools, and access to the remote location, which as a whole, took times. In 1991, the study area was a part of exploration concession of Battle Mountain Gold Company. This recent research is conducted through financial support of Bureau of Energy and Mineral Resources of Mamberamo Raya Regency, Papua Province. The objective of this research is to evaluate stream

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sediment characteristics of the Baedisifu River, and its relationships with the occurences of gold and copper mineralizations. Morphological factors were also used to analyze the lithological conditions and drainage patterns. For the steep slope area in highlands morphology, the stream sediment sampling was have to be conducted by flying camp.

MATERIALS AND METHODS

Materials

The regional stratigraphy of the study area and surroundings were characterized based on comparisons of Indo-Australian continental and Pacific-Caroline oceanic crusts stratigraphies. Stratigraphy of the continental affinity was indicated by the Bird Head (Western Papua) and the Bird Body (Central Range), while stratigraphy of the oceanic affinity was indicated by the Northern Bird Body (Northern Irian Basin). Regional geological map of Papua (*after* Dow *and* Sukamto, 1984; Figure 1).

At the south, the Roufaer metamorphics exposed in east-west trend, on highlands topography. The Baedisifu River is emptied to the Mamberamo River which flowing to the north. Mamberamo River is the biggest river in Papua island, which divides the Roufaer Mountain at the west and Gauttier Mountain at the east.

The are three main periods of geological history of Eastern Indonesia and northwestern part of Australian platform. The first was marked by formation of Indo-Australian continental margin during Permian to Early Mesozoic, as a product of the Gondwanaland break-up. This was followed by a passive period of the continental margin during Late Mesozoic, and continued to Late Miocene. The later period was marked by tectonic convergent of the Indo-Australian continental margin and the Southeast Asia Arc that was took place until the end of Late Miocene. The islands in East Indonesia region were began to formed during the third period.

Some local carbonate buildups was formed as an effect of laterally facies changing. The sedimentary units include Auwewa, Darante, and Makats Formation. After a hiatus, deposition of Mamberamo Formation took place, and continued without interrupted until a small unconformity

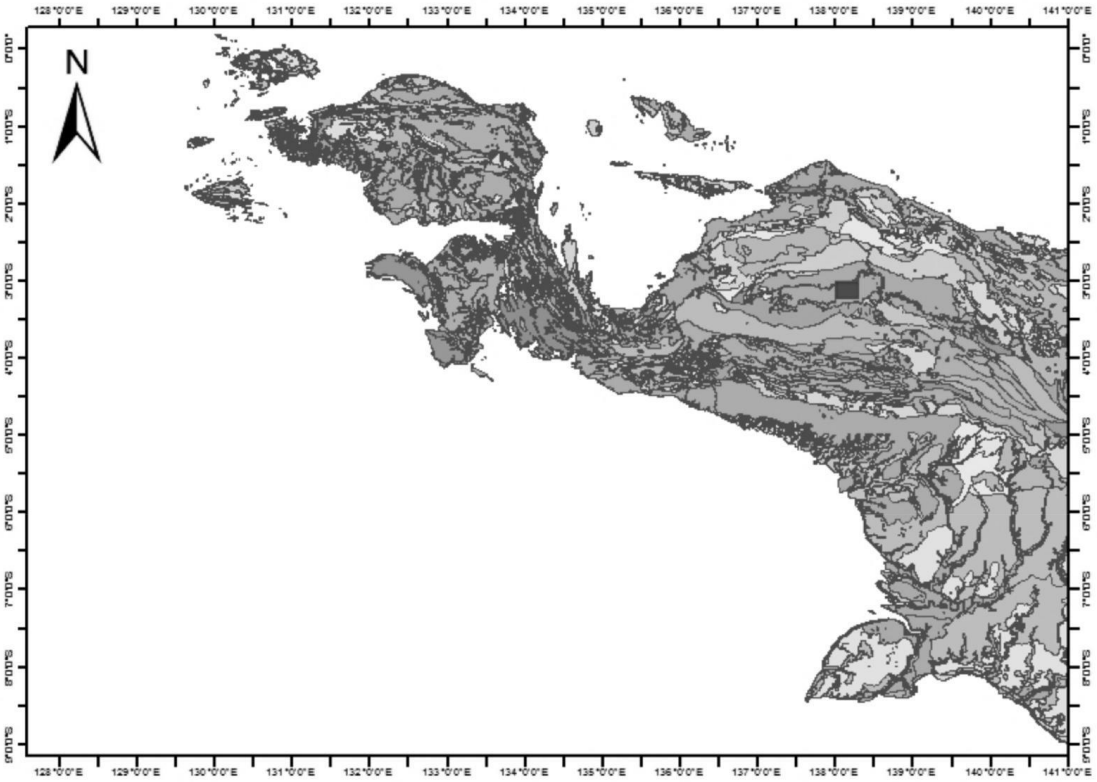

Fig. 1. Regional geological map of Papua (*after* Dow *and* Sukamto, 1984) and the research area (not to scale).

formed in recent time. Regional stratigrafi of the Northern Papua Utara was not well-defined, and its lateral facieses relationships was less understood from outcrops observations. Almost all the sediment sources were at the southern, from massive magmatic arc and from uplift of collisional orogen. Volcanoclastics may be found in the lower parts of Auwewa and Makats Formation, but evidences indicated that erosion of continent from ogoren formation in the south supplied a hugh sediments to the Mamberamo Formation.

Stratigraphy of the Bird Body at the northern are generally consist of Pre-Tertiary ophiolite and volcanics, which were covered by Tertiary sedimentary rocks. The Pre-Tertiary basement include intermediate-basaltic volcanic rocks, ophiolite, schist, basalt, gabbro, and serpentinite. Eocene to Oligocene marine sediments which composed of coarse to fine clastic rocks, carbonaceous clastics, and vbatuan klastik kasar – halus, klastik karbonat, as well as volcanoclstics were unconformably overlying the Pre-Tertiary units.

METHODS

Stream sediment samples were analyzed using ICP-OES, AAS and petrography methods which aimed to identify the relationships between statistical charactersitics of elements contained in the Baedisifu stream sediments with mineralizations in related lithologies.

Four stream sediments samples (80 mesh) and two altered igneous rocks samples for petrographic (AD/OC-011 and AD/OC-018), and ore microscopic analyses were collected (Figure 2). For chemical analyses of X-ray fluorescence, ICP-OES and AAS methods, the samples were sent to be prepared and analyzed in a commercial research laboratory, PT. Intertek Utama Services, Jakarta.

The petrography and ore microscopy were performed in Optical Mineralogy Laboratory, Department of Geological Engineering, Hasanuddin University. From the chemical analyses, as much as 46 elements of major and trace were determined, but only elements considered associated with sulphide mineralization such as As, Pb, Mo, Cu and Zn, were statistical analyzed. Sampling of stream sediments were conducted randomly which supported by observations of rock outcrops around the sample locations. Rock-chip samples from outcrops and rock-float samples along the river were also collected that will be used as dependent factor in statistical tests.

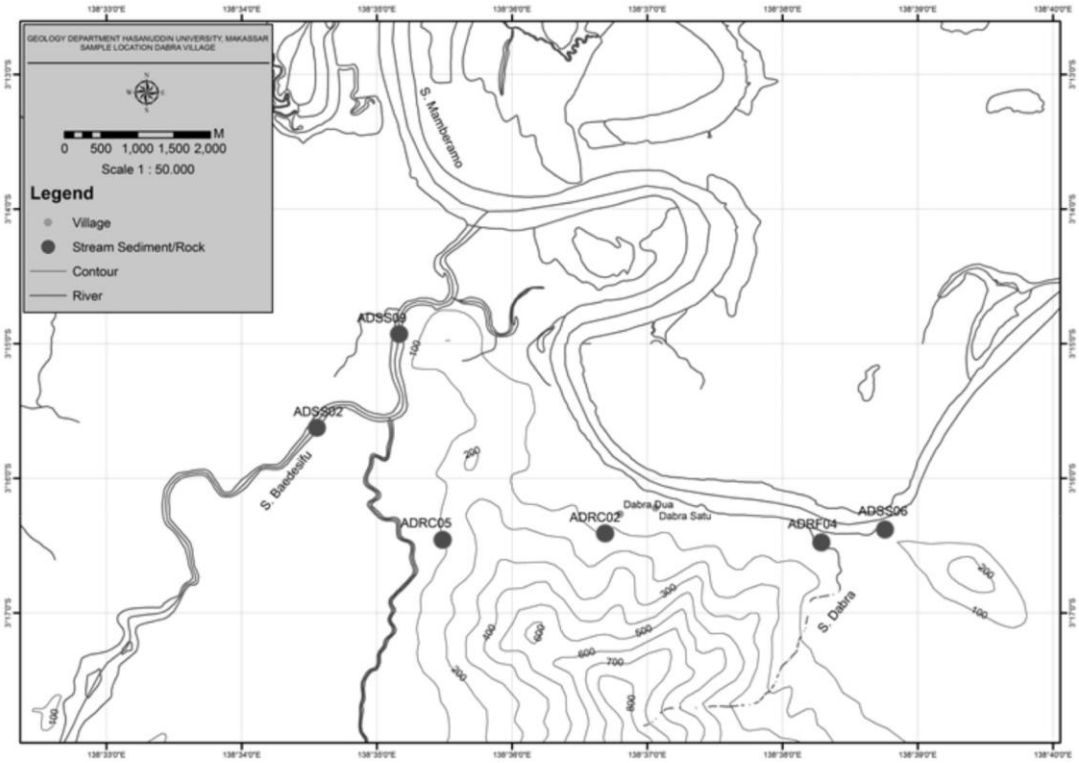

Fig. 2. Sampling point map

Statistically, stream sediment and rocks data (AD/SS-02, AD/SS-06, AD/SS-09, AD/RC-02, AD/ RF-04, AD/RC-05), were tested by hierarchy system proximity matrix method with cluster dendogram analysis using SPSS IBM v.22 software.

RESULTS AND DISCUSSIONS

A. Geomorphology

Geomorphology of the study area is divided in three units.

1. Low Relief Morphology

Low relief morphology unit is distributed on 100 m to 150 m above sea level (a.s.l.), with the slope less than 70^{o}. This unit is arranged by unconsolidated sandstone which strongly weathered forming soil and aluvium, and some covered by bush and swamp. Swamps are common in this morphology unit, and meanders of Baedisifu River are connected with other rivers such as Apauwar River, Biri River, Tor River, and Tariku River; "oxbow lake" also occurred (Figure 3).

Fig. 3. Meanders of Baedisifu River – Apauwar River, Biri River, Tor River, Tariku River and Mamberamo River.

2. Moderate Hills Morphology

Moderate Hills Morphology unit is distributed on 150 m to 500 m a.s.l., with the slope range of 50^{0} to 80^{0}. In several area, this unit is strongly controlled by geological structures. Several main rivers such as Memberamo River, Apauwar River, Muwar River, and Verkam River have drainage pattern that parallel to fold structure, dan some local fault, forming the Baidesifu River. This morphology unit is arranged by stronglt weathered sandstone which covered by moderate to heavy vegetation, contact with igneous rocks occurred in places. This unit distributed broadly which includes Kasonaweja, Apauwar River, Tor River, Biri River and south of Gauttier Mountain (Figure 4).

Fig. 4. Morphological view of moderate hills unit, and the Mamberamo River

3. Steep Hills Morphology

This unit is characterized by elevations of more than 600 m above sea level, and covering the summit of Siduarsi Mountain (830 m a.s.l.), Gauttier Mountain (2160 m a.s.l.), Foja Mountain (2193 m a.s.l.) and Van Rees Mountain. Other characteristics include very steep slopes, "V" form valleys, difficult to access, particualrly around the summits, lot of water falls (Figure 5). This unit is generally arranged by older rocks which are mostly massive and harder compared to the surrounding lithologies. One of the water fall drainage entering the Baidesifu River, which eventually empties to Mamberamo River.

Fig. 5. Junction of Baedisifu River and Mamberamo River on the steep hills morphology unit

B. Geological Structure

Geological structures develop in and around the study area include fault and fold. Mamberamo thrust forming a corridor about 100 km extending southward. A strike-slip fault also recorded in lithologies of Mamberamo Formation and underlying Pacific rocks. Field data showed that the structure patterns are irregular and generally in northeast-southwest trend. Figure 6 shows outcrop of brownish andesite that intensively jointed in generally north-south strike. The rock is weakly to

moderately altered, contains chlorite; thin oxidized quartz vein also observed, with disseminated pyrite, chalcopyrite, and less covellite.

Fig. 6. Joints in andesite outcrop.

C. Petrography

Andesite (AD/OC-11) brownish yellow, porfiroaphanitic texture, 0.06 to 0.8 mm minerals grain size, subhedral to anhedral minerals shape, greyish white interfrence color, mineral composition: andesine plagioclase (10 to 15%), orthoclase (10%), and hornblende (5 to 7%), alteration minerals: quartz microcrystalline (5 to 20%) and sericite (12%), plagioclase microcrystalline (60 to 70%) (Fig. 7). This rock showed indication of surface alteration from a metamorphic system, which generally forms advanced argillic alteration.

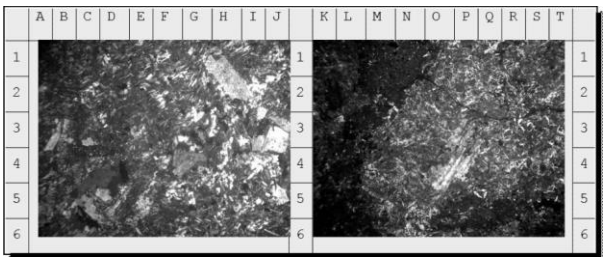

Fig. 7. Photomicrograph of altered andesite, with orthoclase (5C), plagioclase (2H, 4P), hornblende (3H, 3K-L), quartz microcrystalline (2I), sericite (5M), microcrystalline plagioclase groundmass (2F, 1P).

Diabase (AD/OC-18) brownish yellow absorption color, brownish grey interfrence color, diabasic, 0.3 to 0,8 mm minerals grain size, composed by labradorite plagioclase (50%), augite pyroxene (35%), hornblende (10%), and opaques (5%). The minerals grain size of the both andesite and diabase indicate a similar effects of metamorphic grade, which initiated in andesite.

Colloform Texture: Diorite float sample (AD/OC-9) showing dark brown grey color, strongly altered, strongly oxidizing silicified of monmorillonite, and traces of sulphides and disseminated oriented pyrite. Under the microscope, polished section showed disseminated gold, sphalerite, iron, and pyrite intergrows with chalcopyrite; a colloform textute showed, where colloidal pyrite occurred in chalcopyrite. Metamorphism and rock deformation effects have caused the sulphide fluid and pressure to form pyrite filled space and cleavage of the rock (Fig. 8).

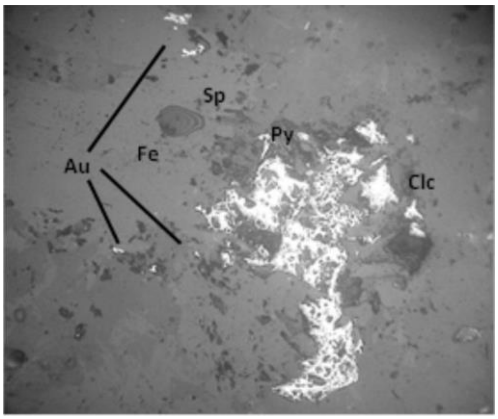

Fig. 8. Photomikrograph of altered diorite (AD/OC-09), gold (Au), iron (Fe), sphalerite (sp), pyrite (py), chalcopyrite (clc).

D. Statistics

Results of AAS and ICP-OES analyses on stream sediment, rock chip, and rock float samples are shown in Table 1.

Proximity matrix analysis on rock and stream sediment samples, resulted squared Euclidean distance of Au→Ag(0.27), W(0.57), Bi(0.89), Mo(7.78); As→Sn(69.01), Mo(73.53), Pb(83.8); Cu→Pb(27304.56), Mo(28801.29), Au(29261.09); Pb→Ag(240.31); Mo→Au (7.78), Ag(8.30), Sn(2.8); Ag→Sn(3.72).

This indicates that element accumulation in different kind of samples will offer many possibilities of mineralization group. Distance of As is shorter relative to Cu which has bigger Euclidean distance to metals, that indicates that mineralization occurred in andesite is characterized by a closed-relationship of As with other metals of Au and Mo. Sulphide metal mineralization which represented by

Table 1. Results of AAS and ICP-OES analyses (in ppm)

	AD/SS-02	AD/SS-06	AD/SS-09	AD/RC-02	AD/RF-04	AD/RC-05
Au	0.02	0.02	0.13	0.02	0.02	0.02
As	4.9	2.8	4.3	3.3	5	4.3
Cu	26.2	16.6	46.6	116	24.4	110
Pb	10.3	9.5	3.8	0.5	4.9	3
Mo	0.4	0.3	2.8	0.4	0.4	0.4
Zn	65	53	75	29	49	24
Ag	0.14	0.02	0.02	0.02	0.02	0.02
Sn	0.9	0.6	1.3	0.5	0.8	0.6
W	0.09	0.2	0.09	0.1	0.09	0.1
Bi	0.2	0.19	0.13	0.13	0.08	0.13

Cu is characterized by closed-relatioship of Pb and Zn. The presence of these elements is typical for porphyry copper gold deposit. Based on proximity matrix and dendogram cluster membership, there are six groups of mineralization: (1) Au, W, Bi, Mo
(2) As, Sn, Mo, Pb (3) Cu, Pb, Mo, Au (4) Pb, Ag (5) Mo,Au, Sn (6) Ag, Sn (Figure 8). There is difference of cluster in those groups, where As, Mo, Pb are clustered in one group, and Cu and Zn clustered in other group. This indicates a mineralization process of Au-Cu-Mo, Cu-Pb-Zn metals of a porphyry copper system (Figure 9).

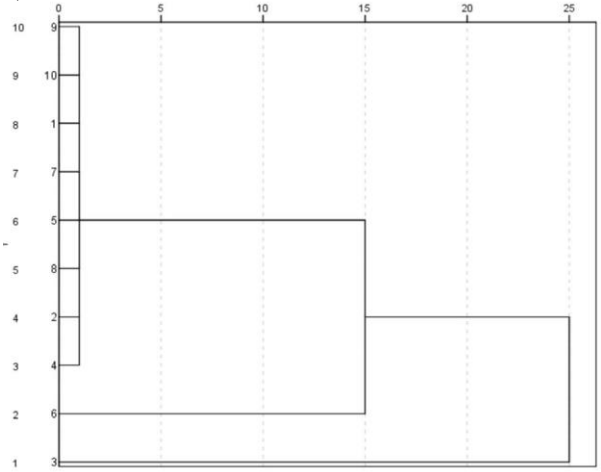

Fig . 9. Dendogram showing relationships stream sediment (SS), rock chip (RC), rock float (RF) samples, and element clusters.

Proximity matrix analysis was also performed on samples AD/RC-02, AD/RF-04, AD/RC-05 and elements Au, As, Cu, Pb, Mo, Zn, Ag, Sn, W, Bi. Squared Euclidean distance resulted four clusters of elements distances, as follows: (1) Au→Ag(0.0) Mo(0.0) Pb(0.0) (2) Cu→ Mo(4.0) Ag(2.0) Sn(0.16) (3) Pb→Cu(7.42) Zn(1.19) (4) MoAg(0.0) Au(2.0). It shows that chip sample taken from outcrop

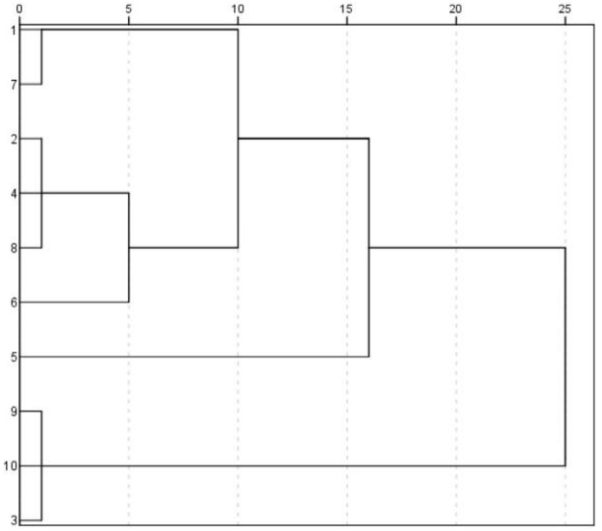

Fig. 10. Dendogram showing relationship between cluster of rock samples and cluster of elements As, Mo, Pb, Ca, Zn.

(andesite) as well as river float sample (metamorphosed altered andesite boulder), have a relationship in mineralization process, although they are different in lithology. Element Mo are more regularly dispersed in the rock samples compared to As and Cu, and this is also indicated by the dendogram in Figure 10. The element Mo is singularly positioned from the As, Mo, Pb and Cu cluster.

CONCLUSION

The research is conducted in the Gauttier Highlands, where its mineralization is a part of Central Papua mineralization system. The mineralization is extended to the northern and southern parts, which are covered by Mamberamo sediments. Stream sediment evaluations indicated that there is a spot of intrusion that exposed and forming a low to

moderate morphology. The characterististics of intrusion and mineralization indicate a metamorphosed perypheral porphyry copper deposit. Statistical analysis suggested that andesite, diabase, diorite indicate a similar metamorphic deformation system on the Au-Cu-Mo and Cu-Pb-Zn mineralization.

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